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DEPARTMENT OF ARCHITECTURE
COLLEGE OF ARCHITECTURE ▪ TEXAS A&M UNIVERSITY

BACHELOR OF ENVIRONMENTAL DESIGN

MASTER OF ARCHITECTURE

MASTER OF SCIENCE IN ARCHITECTURE

MASTER OF SCIENCE IN VISUALIZATION SCIENCES

DOCTOR OF PHILOSOPHY IN ARCHITECTURE

COVER PAGE

RE: Final Performance Report for the National Endowment for the Humanities

High Dynamic Range Imaging for Preserving Chromaticity Information of Architectural Heritage

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Name of Project Director: Wei Yan

Name of Grantee Institution: Texas A&M Research Foundation

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NARRATIVE DESCRIPTION

- Final Performance Report

High Dynamic Range Imaging for Preserving Chromaticity Information of Architectural Heritage

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The goal of this project is to develop a method to assist in recording and documenting the intrinsic chromaticity information of building interiors and exteriors of architectural heritage with low cost and high efficiency. The method takes advantage of the emerging High Dynamic Range Imaging (HDRI) technology, which can store rich information about color and illumination through digital photography. By recording the color information, in addition to the geometry and texture information that can be obtained through other technologies, we can achieve more complete documentation for architectural heritage.

1. Project Activities

Our major activities of the project including:

a. Literature research. We have conducted literature research on existing methods in color documentation: (a) manual observation; (b) archive study and research; and (c) paint analysis. In addition, we have also reviewed the related background of digitization of historic buildings, HDRI, tone-mapping, exposure-fusion, and shadow removal.

b. Research of image processing methods that utilize HDRI and integration of cast shadow and form shadow removal to assist in recording and documenting the chromatic information of interiors and exteriors of historic buildings. We have proposed and tested a new method of using multiple exposures and time varying images to retrieve the building surface chromatic information.

c. Implementation and development of a prototype to test the methods. We have developed a prototype computer program using Matlab programming language. The implementation consists of two stages: pre-processing to construct exposure- and time-fusion images, HDR images, and segmentations; and main processing to obtain the final color grouping that is based on the chromatic information of surface areas.

d. Experiments with lab settings. In the lab setting experiments, we used our algorithm to process images of colored objects, such as plastic and wood blocks. The input images of different exposures were taken at different times of a day using a digital camera with a fixed aperture and varied shutter speeds. The images were processed using our prototype.

e. Experiments in the field at the Hall of Supreme Harmony in the Forbidden City, Beijing. The Hall of Supreme Harmony is the largest building within the Forbidden City, a UNESCO World Heritage Site. The hall is one of the largest wooden structures within China. Photos were taken on January 10, 2009, in the Forbidden City, using a digital camera with a fixed aperture and varied shutter speeds. The images were processed using our prototype.

f. Analyses and evaluation of the experiment results. Processing results, processing time, effects of parameter values, and limitations were studied.

g. Publishing the research results. Two conference papers have been published during the project period. One journal paper is currently under review and revision.

2. Accomplishments

The immediate goal of our methods is to classify intrinsic colors by grouping the same colors spread in different segments, caused by different surface materials and lighting, and reduce the number of color regions on the final images towards the ideal results: all regions of the same color are labeled and re-colored the same, and the number of labels is the same as the actual number of colors in the scene.

In both lab and field experiments, on the original images there is a large number of different color areas, caused by both the surface material difference and the lighting difference. On the resulting images, the numbers of regions are reduced significantly. Our color classification results indicate that the experiments achieved significant reduction of the numbers of regions and made them much closer to the actual numbers of colors in the experiment scenes. The reduction of the number of color regions will potentially make later physical color sampling and measurement more efficient.

Because of missing color information in highlight areas in low dynamic range images, it is normally difficult to recover colors in such highlight areas. In order to resolve this problem, our image fusion algorithm uses both different exposure and difference time-set images to better capture the color information in the highlight area than using exposure-fusion only. The highlight area is successfully recovered – the color of this type of areas is classified correctly in our experiments.

3. Audiences

Documentation of chromatic information for historic buildings can provide important information on the buildings' significance for use by researchers, preservationists, and others interested in preserving and understanding historic buildings. The method can be used to model surface colors to reflect the present conditions of historic buildings and assist in the education of cultural heritage, therefore can be used by educators.

4. Evaluation

In our project, we have conducted analyses and evaluation of the experimental results. Our image processing results, processing time, effects of parameter values, and limitations were studied. We think the results are promising for digitizing and documenting the surface colors of historic buildings and for later assisting color matching and paint analysis.

The project methods and results have been evaluated through peer reviews in journal and international conferences in the fields of cultural heritage preservation and computer vision. Two papers have been accepted and published as of today and another one is in the process of revision/review. For the one under revision/review, one of the reviewers has given the following comments: "the paper offers an original contribution both to the knowledge and to the practice of the cultural heritage digital documentation research area", while the other reviewer requests "some points to be deepened and clarified", for which we are working on.

5. Continuation of the Project

Our future work of the project includes: improving the current methods by devising a way to deal with inter-surface reflections; assigning physical color measurements, such as CIE L*u*v*, with the calibration of a spectrophotometer, to pixels representing surface samples; conducting more case studies in selected historical buildings; and investigating the integration of digitizing colors and digitizing geometries for historic buildings. In addition, we will investigate the integration of our method with photogrammetry technique to digitize historic buildings' color and geometry simultaneously. Since photogrammetry requires obtaining digital photographs, we can utilize the photos to document colors if multiple exposure and multiple time sets of photos are taken.

In the current experiments, user interaction is required to adjust parameters to achieve good processing results, but it is expected that some user interaction may be automated in the future using Machine Learning and Patten Recognition techniques. In addition, a

study of the application of the method in monitoring color fading process needs to be conducted through simulations of the decaying process of building materials.

In order to provide end users - professionals in the field of architectural heritage - with an easy-to-use software application, without exposing them to details of image processing algorithms and requiring them to understand the algorithms, we will conduct a user study to help create a user-friendly software interface. Intuitive key parameters will be identified so that users can easily understand and manipulate them to preview the desired end results. A user manual will be created to explain how a particular parameter can be varied and what should be expected to change in the results.

One of the graduate students working on this project is currently continuing the research on using the machine learning technology to improve the image processing, which is the topic of his Master's thesis.

A new grant proposal is under planning to support the future work.

6. Long Term Impact

The expected long term impacts of this project in the fields of cultural heritage research and education include:

a. The method assists documenting the surface colours of the current state of historic buildings. Colors on both small and large surfaces can be retrieved with automatic image processing on photographs of historic buildings.

b. Documentation for historic buildings can provide important information on the buildings' significance for use by researchers, preservationists, and others interested in preserving and understanding historic buildings. Digitizing the color information, in addition to the geometry information that can be acquired by other means, is a step towards complete documentation.

c. The method can be used to model surface colors to reflect the present conditions of historic buildings and assist in the education of cultural heritage.

d. The method has the potential to be used for monitoring and detecting the color change (e.g. color fading) of historical buildings if the recording and measurement are done on a regular basis.

e. The method can assist in automatic classifying colour regions to facilitate efficient sampling in paint analysis by reducing the number of samples that is needed for analysis. The method helps in finding of representative colour regions where samples can be extracted.

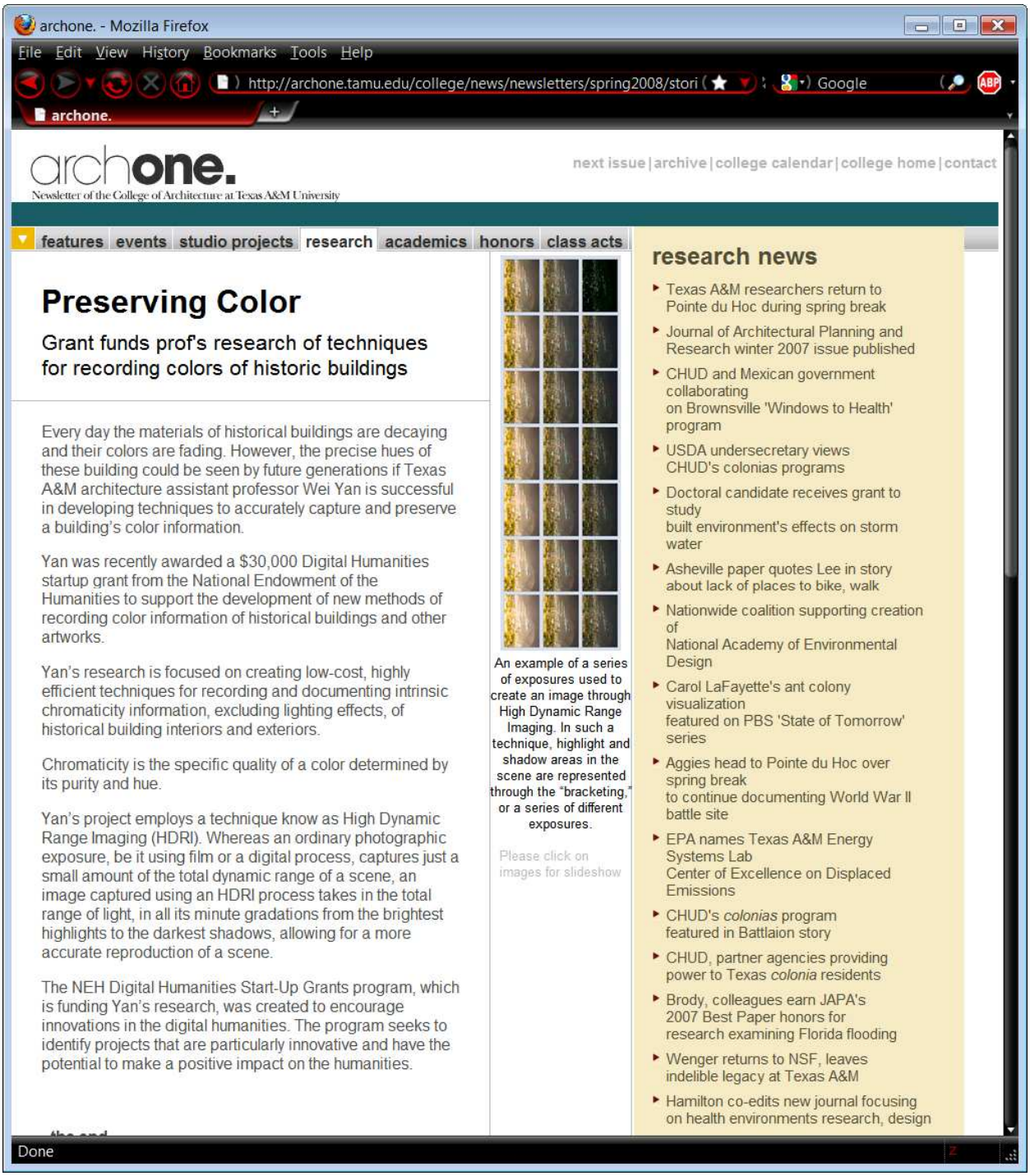
7. Grant Products

The grant products include new methods and algorithms developed during the project period and publications in international conferences. One journal paper is in the process of revision/review. A project website is under construction.

Appendices

A. Newsletter

http://archone.tamu.edu/college/news/newsletters/spring2008/stories/weiColor.html



B. **Project publications**

Peer-reviewed publications:

Rajan, P and Yan, W. “Cast Shadow Removal Using Time and Exposure Varying Images”, *Proceedings of The 7th International Conference on Advances in Pattern Recognition (ICAPR)*, Kolkata, India. IEEE Computer Society Press, 2009. pp. 69-72

Yan, W. and Rajan, P. “Towards Digitizing Colours Of Architectural Heritage”, *Proceedings of The Conference on Virtual Systems and MultiMedia (VSMM) '08: Dedicated to Digital Heritage*, October 20 - 25th, 2008, Limassol, Cyprus. pp. 238-245.